

PL 980498

REC'D 01 APR 2003

PCT

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

**UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office**

March 26, 2003

**THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM
THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK
OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT
APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A
FILING DATE.**

APPLICATION NUMBER: 60/353,849

FILING DATE: February 01, 2002

RELATED PCT APPLICATION NUMBER: PCT/US03/03181



**By Authority of the
COMMISSIONER OF PATENTS AND TRADEMARKS**

W. Montgomery
W. MONTGOMERY
Certifying Officer

**PRIORITY
DOCUMENT**

SUBMITTED OR TRANSMITTED IN
COMPLIANCE WITH RULE 17.1(a) OR (b)

BEST AVAILABLE COPY

02-05-02

Alper

Please type a plus sign (+) inside this box → ☐

PTO/SB/16 (8-00)
 Approved for use through 10/31/2002. OMB 0651-0032
 U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
 This collection of information unless it displays a valid OMB control number.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

INVENTOR(S)		Residence (City and either State or Foreign Country)
Given Name (first and middle [if any])	Family Name or Surname	
Cheng C. Barry	Ko Levine	713 Skynob Dr., Ann Arbor, Michigan 48105 22 Bear Brook Lane, Livingston, New Jersey 07039
<input type="checkbox"/> Additional inventors are being named on the _____ separately numbered sheets attached hereto		
TITLE OF THE INVENTION (280 characters max)		
HIGH SPEED ENHANCED RESPONSIVITY PHOTO DETECTOR		
CORRESPONDENCE ADDRESS		
Direct all correspondence to: <input checked="" type="checkbox"/> Customer Number <u>00757</u> → Place Customer Number Bar Code Label here PATENT & TRADEMARK OFFICE		
OR Type Customer Number here		
<input checked="" type="checkbox"/> Firm or Individual Name <u>Steven L. Oberholtzer</u>		
Address <u>Brinks Hofer Gilson & Lione</u>		
Address <u>P.O. Box 10395</u>		
City	State	ZIP
<u>Chicago</u>	<u>IL</u>	<u>60610</u>
Country	Telephone	Fax
<u>USA</u>	<u>(734) 302-6000</u>	<u>(734) 994-6331</u>
ENCLOSED APPLICATION PARTS (check all that apply)		
<input checked="" type="checkbox"/> Specification	Number of Pages <u>4</u>	<input type="checkbox"/> CD(s), Number <u> </u>
<input checked="" type="checkbox"/> Drawing(s)	Number of Sheets <u>1</u>	<input type="checkbox"/> Other (specify) <u> </u>
<input type="checkbox"/> Application Data Sheet See 37 CFR 1.76		
METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT (check one)		
<input checked="" type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. <input type="checkbox"/> A check or money order is enclosed to cover the filing fees <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number: <u>23-1925</u> <input type="checkbox"/> Payment by credit card. Form PTO-2038 is attached.		FILING FEE AMOUNT (\$) <div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;">\$80.00</div>
The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government. <input checked="" type="checkbox"/> No. <input type="checkbox"/> Yes, the name of the U.S. Government agency and the Government contract number are: _____		

Respectfully submitted,

SIGNATURE


TYPED or PRINTED NAME Steven L. OberholtzerTELEPHONE (734) 302-6000

Date

2/1/02
 REGISTRATION NO. 30,670
 (if appropriate)
 Docket Number: 10555-030

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

This collection of information is required by 37 CFR 1.51. The information is used by the public to file (and by the PTO to process) a provisional application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 8 hours to complete, including gathering, preparing, and submitting the complete provisional application to the PTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Washington, D.C. 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Box Provisional Application, Assistant Commissioner for Patents, Washington, D.C. 20231.

P19SMALLUREV05

CERTIFICATE OF MAILING BY "EXPRESS MAIL" (37 CFR 1.10)

Applicant(s): Ko et al.

Docket No.

10555-030

Serial No.

Filing Date

Examiner

Group Art Unit

Invention: High Speed Enhanced Responsivity Photo Detector

I hereby certify that this Provisional Application, Transmittal Letter, and One Sheet of Drawings
(Identify type of correspondence)

is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under
37 CFR 1.10 in an envelope addressed to: The Commissioner of Patents and Trademarks, Washington, D.C.

20231-0001 on February 1, 2002
(Date)

M. Collins

(Typed or Printed Name of Person Mailing Correspondence)

M. Collins

(Signature of Person Mailing Correspondence)

ET719098306US

("Express Mail" Mailing Label Number)

Note: Each paper must have its own certificate of mailing.

20231-0001-020102

HIGH SPEED ENHANCED RESPONSIVITY PHOTO DETECTOR

BACKGROUND

There is a well-known tradeoff between high speed and sensitivity in a photodetector. High bandwidth requires a short transit time and thus a thin absorber layer, which results in a reduced absorption and lower responsivity. This proposal describes a way around this problem, with an enhanced absorption photodetector design.

The closest previous detector is the "uni-traveling carrier" ("UTC") detector. This is substantially different as follows:

The UTC detector has the *entire* absorption region heavily doped with *no low doped drift absorption* region where the carriers travel with their saturation velocity.

The UTC detector has a collector region in a high bandgap region which has *no absorption* and where the electrons do travel with saturation velocity. The detector discussed here has no high bandgap region where there is no absorption, and thus no drift region without absorption.

Because of this electron drift region, the UTC detector has several carefully designed interface layers and interface doping to optimally adjust the bandgap discontinuity between the low gap absorption and high gap drift regions. The detector discussed here needs no such layers.

Because there is no "wasted" drift region without absorption, the enhanced detector discussed in this patent is expected to have a superior performance at high speeds such as 40Gb/s.

201020-6485509

DESCRIPTION

In an embodiment of the present invention, in the enhanced photodetector, the heavily doped p anode region in the absorption region of the detector (e.g. PIN, APD etc.) is concentration graded from a high p concentration near the anode to a lower p concentration towards the cathode. By grading the doping in this way, a pseudo-field is created which gives the electrons a very high velocity in this highly doped region, even higher than their saturation velocity in the low doped drift region.

The operation of this detector is summarized as follows:

The light is absorbed in the low bandgap absorption region (e.g. InGaAs) of the detector. The light which is absorbed in the low doped (high field) part of the absorber produces electrons and holes that drift to the anode (holes) and cathode (electrons) under the influence of the large drift electric field. This field is so large that both the electrons and holes reach their saturation velocities. This is the usual situation in standard uniformly low doped absorber PIN photodetectors. In the enhanced detector, however, the photoresponse is more complex.

The electrons generated in this low doped part of the absorber reach the cathode with their saturation velocity and are collected as usual. The holes generated in this low doped part of the absorption region reach the edge of the absorption region where the doping starts to become high and where they can be electromagnetically collected in a very short dielectric relaxation time (typically requiring a doping of $\sim 10^{16}$), thus ending their transit time. Since the dielectric relaxation is so short, the holes do not have to

20170220 14:20:10 60353849

transit all the way across the heavily doped p region, and thus, their transit time is the same as if the extra p absorber material was not there.

The light that is absorbed in the heavily doped p region also produces electrons and holes. These holes are collected electromagnetically which is essentially instantaneously, and thus do not add substantially to the transit time or reduce the detector bandwidth either in the high-doped or the low doped absorber regions.

The electrons generated in this highly doped region are subject to the pseudo-field created by the doping gradient.

$$F = - (kT/q) dp/dx$$

This pseudo-field F is designed so that it produces an "overshoot" electron velocity, i.e. the electron velocity can be made to be many times faster than the saturation velocity. For example, in an exponential gradient

$$p = p_0 \exp(-x/L)$$

with $L=800\text{\AA}$ yields a field $F=3.25\text{kV/cm}$. (Typical electron saturation velocities are only $\sim 5 \times 10^6$ cm/sec, whereas overshoot velocities can be as large as $\sim 4 \times 10^7$ cm/sec at fields F of the magnitude given above). Thus, the electrons can quickly escape from this heavily p doped absorption region, adding little to the transit time.

In summary, an extra absorption region if properly doped can be added to the drift region in the low bandgap absorber without substantially increasing the transit time or the capacitance, i.e. without substantially reducing the overall bandwidth. Of course, it may

be advantageous to optimize the overall speed by adjusting the doping, the capacitance and the total thickness of the absorption region.

As an illustrative example of one embodiment of the present invention only: A standard 0.6 micron thick absorption layer PIN with low doping has a transit time limited bandwidth of ~50 GHz. For comparison, this same transit time bandwidth can be achieved with a 0.8 micron thick absorption layer with an exponentially graded p doping ($L=800\text{\AA}$). Thus, in this example, the single pass responsivity is increased from 34% to 42% (an improvement of 24%) while keeping the transit time limited bandwidth approximately constant. For a mirror reflectivity of 70% the responsivity improvement is from 49% to 59% (an improvement of 20%).

201020-6485209

207020-6485509

Figure 1

Graded p-Doping Enhanced Absorption Detector

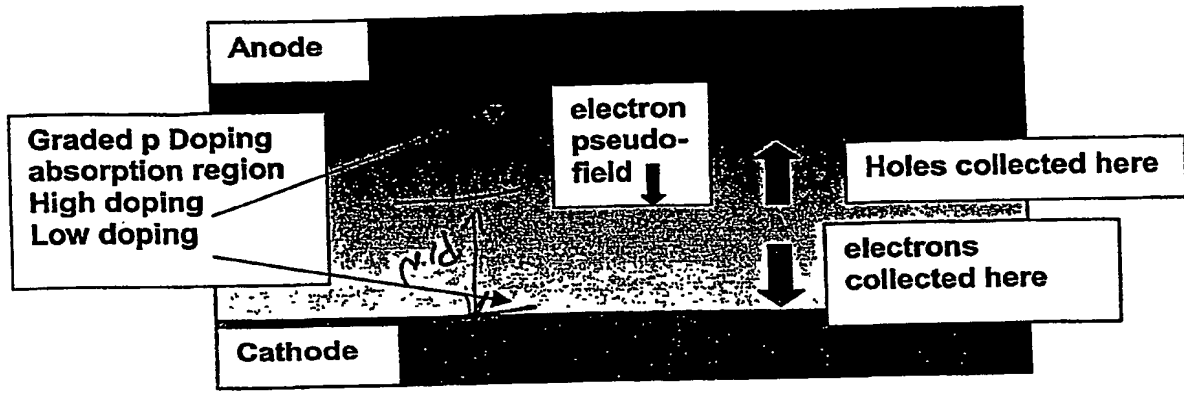
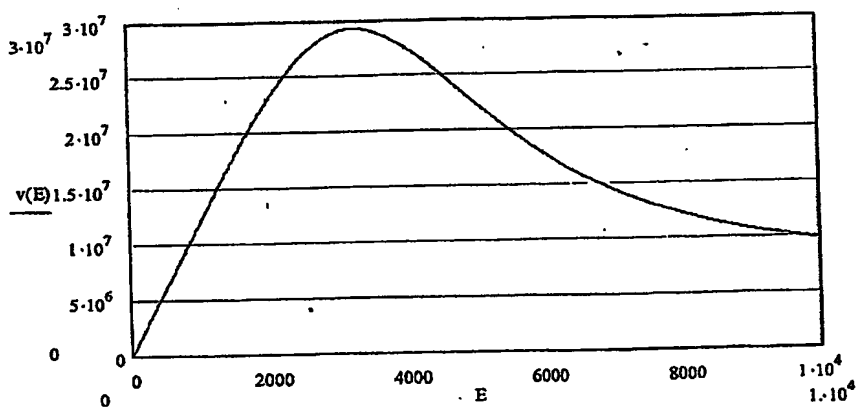


Figure 2

Electron Overshoot Velocity



**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☒ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☒ FADED TEXT OR DRAWING
- ☒ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☒ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☐ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.